MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2017/2018

ENT4066 – NANOELECTRONICS MATERIALS AND DEVICES

(NE)

31 May 2018
02:30 p.m. - 04:30 p.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 5 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

(a) Discuss the **TWO(2)** necessary conditions for observing the Coulomb blockade effect.

[6 marks]

(b) A square parallel-plate nanocapacitor has a capacitance of 20 aF. The side length of the square plate is denoted as L, and the separation distance between the plates, d, is $L/12$. Answer the following:

(i) Determine the applied voltage, V, where Coulomb blockade occurs.

[2 marks]

(ii) Determine the temperature, T, for Coulomb blockade to be observed.

[2 marks]

(iii) Determine the number of electrons that could be transferred due to thermal fluctuations, assuming operation at 400 K.

[2 marks]

(iv) Given that the permittivity, ε, of the material separating the plates is 8.85×10^{-12} $F\cdot m^{-1}$, determine both the length, L, and the separation distance, d, in order to observe the Coulomb blockade at 400 K.

[3 marks]

(c) (i) Draw the diagram of the *total change of free energy*, ΔG, as a function of *radius*, r, of the solid nucleus. Explain the diagram.

[3+4 marks]

(ii) Based on the diagram answered in **Q1(c)(i)**, discuss the temperature effects on nucleation.

[3 marks]

Continued...

QUESTION 2

(a) (11, 4) single-wall carbon nanotube (SWCNT) can be considered as rolled-up a small sheet of graphene along its vector directions into a seamless cylinder. Answer the following:

(i) Given that the carbon-carbon (C-C) bond length is 0.142 nm, determine the diameter of the CNT.

[1.5 marks]

(ii) Determine the chiral angle of the CNT.

[1.5 marks]

(iii) Determine the chirality and the type of conductivity of the CNT.

[2 marks]

(iv) Illustrate the *E-k* diagram and density of states (DOS) of the CNT.

[4 marks]

(b) (i) Discuss the effects of metal catalysts on the growth of single-walled (SWCNTs) and multi-walled CNTs (MWCNTs) respectively.

[3 marks]

(ii) With the aid of suitable diagram, explain the tip-growth mechanism in the growth of CNT.

[3+4 marks]

(c) Analyze the electronic transport properties of metallic CNT and graphene respectively.

[6 marks]

Continued...

QUESTION 3

(a) Differentiate the three scaling rules; *constant field scaling*, *generalized scaling* and *generalized selective scaling*, of metal-oxide-semiconductor field-effect transistor (MOSFET).

[6 marks]

(b) Explain the typical short channel effects (SCEs) that will be arisen during the miniaturization of MOSFETs as in the following:

- Subthreshold current, I_{off}
- Drain-induced barrier lowering (DIBL)

[6 marks]

(c) (i) Sketch the schematic structures of partially-depleted (PD) and fully-depleted (FD) silicon-on-insulators (SOIs) MOSFETs.

[5 marks]

(ii) Comment on the *floating body effect* (FBE) in PDSOI and FDSOI respectively.

[8 marks]

Continued...

QUESTION 4

(a) **Figure Q4(a)** shows the charge stability diagram of a single electron transistor (SET), whereby the number of electrons of the island is plotted as a function of drain-source voltage (V_{ds}) and gate voltage (V_g). Explain the stability diagram.

[5 marks]

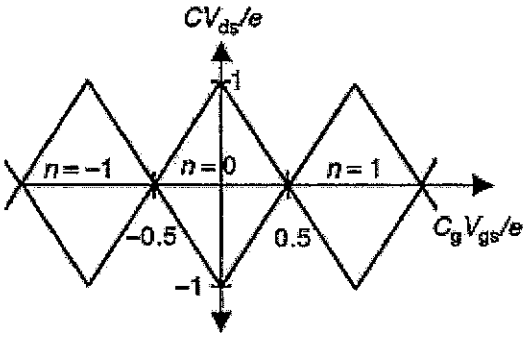

Figure Q4(a)

(b) Discuss the three main requirements: create spin, control spin and detect spin, in realizing the spintronics devices, respectively.

[9 marks]

(c) (i) Sketch the energy level diagram that illustrating the quantum-dot light-emitting diode (QD-LED), and explain how the QD-LED works.

[4+5 marks]

(ii) Explain briefly how luminescence colour can be tuned over the entire visible wavelength range in QD-LED.

[2 marks]

End of Paper